TEMPERAMENTAL CONTRIBUTIONS TO HUMAN DEVELOPMENT: The Biological Characteristics of Infants Influence Their Initial Behavior to Unfamiliar Contexts

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Explanations of the stable sources of variation among children and adults in dominant emotional mood, habitual style of social interaction, and energy investment in goal directed behavior vary with culture, as well as historical era. Most explanations assign causal power either to external conditions—climate and diet in prescientific societies and social experience in modern ones—or to inherent qualities of the person—which in the past were presumed to be marked by features like date of birth but are regarded now as partial derivatives of an individual's genotype.

The contemporary theoretical view among Western scholars is at the end of a cycle, about 75 years old, that awarded extraordinary formative power to experiences within the family during the early years. This interpretation is being complemented by recent evidence pointing to the influence of inherited biological processes, usually called temperamental, on the behavioral and emotional profiles of children. Because the idea of temperament is still in an early phase of its renaissance, there is some disagreement over both its sense and referential meanings. A majority of investigators prefer to restrict the term temperament to a small number of continuous qualities, especially sociability, intensity of emotional reaction, and activity level, and often use as evidence questionnaires in which subjects reply verbally to queries about their own or other's typical behaviors and feelings.

A DEFINITION OF TEMPERAMENT

Our research group treats temperament as a category and defines it as a profile of inherited neurophysiological processes that is associated with a family of behaviors, emotional moods, and, occasionally, physical features, which, on occasion, can be observed in the infant. Children who belong to any one of the potentially large number of temperamental categories display, over time, an orderly sequence of psychological reactions as they consolidate their encounters with people and events. The specific behavioral constellation actualized in adolescence or adulthood will depend upon the particular environments a child meets. Because these environments, like the weather on a

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long motor holiday, are not completely predictable, scientists can only forecast a family of likely outcomes. They can not predict the exact profile that will emerge from a particular temperamental disposition detected during infancy.

The reader may have noticed that this definition of temperament can also be applied to the heritable behavioral variation noted among or within the strains of an animal species. Cocker spaniels and terriers, as well as rhesus, bonnet, and crabeater macaques, display distinctive behavioral and physiological profiles under both natural and stressful conditions, implying that the infants of each strain will follow different developmental itineraries if placed under the same environmental conditions (Scott and Fuller, 1974; Clarke, Mason, & Moberg, 1988). Indeed, some of the distinctive behaviors that differentiate males and females might be regarded as temperamental qualities (see Holekamp & Sherman, 1989).

A definition of temperament as general as this permits a variety of biological mechanisms to function as the bases of a temperamental category. We suspect that most of the temperamental types to be discovered will have their origin in genetically transmitted profiles of hormones, neurotransmitters, and brain peptides which bias the animal's behavior toward stereotypical responses to particular types of sensory stimulation (Kravitz, 1988). Because the number of such chemical substances in the brain is already over 100, the possible set of neurochemical profiles that could be linked to particular physiological functions and behaviors is very large. We will have to see how many turn out to be functional. Hopefully, the number of coherent, stable temperamental types will be smaller than the number of strains of dogs in the world today. Unfortunately, scientists are unable to assay most of these physiological profiles. Thus, it is useful at present to adopt a Baconian posture and infer the basic temperamental categories from rich sets of behavioral observations and associated biological characteristics. Such an inferential strategy is a distinctive characteristic of the first phase of growth in most of the disciplines within the life sciences.

REACTIONS TO THE UNFAMILIAR

It is not surprising that the first temperamental categories to be elaborated refer to the ways in which children and adults behave initially in unfamiliar situations, and especially with unfamiliar people. A person's typical psychological style with strangers, like the periodicity of the moon, is such an obvious quality one would expect it to be a popular target of study. Phenotypically similar variations exist among most animals. Schnierla's (1965) suggestion that approach or withdrawal from events is a fundamental feature that differentiates animal species has been affirmed in many groups, including mice, rats, cats, dogs, wolves, pigeons, and monkeys. Suomi (1987) and Stevenson-Hinde, Stillwell-Barnes, and Zunz (1980) have found that variation in fearful behavior is among the most stable qualities in monkeys reared in laboratories from infancy to puberty.

The belief that humans differ in the ease in which inhibition of action and/or withdrawal are evoked by the unfamiliar is implicit in Aristotle, Plato, and Galen, Sheldon's typology, and Jung's contrast between introverted and extraverted psychological types. Introverted and extraverted dispositions are the most stable and heritable of

the many adult personality qualities that have been studied (Plomin, 1986; Conley, 1985; Kagan and Moss, 1962). And extreme fearfulness is preserved in some individuals from childhood to adulthood. For example, one-third of a group of 66 children diagnosed as school phobic when they were between four and eleven years of age were still very anxious when they were interviewed ten years later (Coolidge, Brodie, & Feeney, 1964). As might be expected, exremely shy, phobic children were likely, as adults, to select bureaucratic jobs with minimal risk (Morris, Soroker & Burruss, 1954).

LONGITUDINAL STUDY OF TWO TEMPERAMENTAL TYPES

The presumption that these psychological profiles are influenced, in part, by genetic factors implies that one might see their anlage in early childhood. Research in our laboratory over the past eleven years has been devoted to this mission. In the first phase of our work, my colleagues and I—Steven Reznick, Nancy Snidman, Cythia Garcia-Coll, Wendy Coster, Michelle Gersten, along with many others, studied two independent groups of Caucasian children from intact middle and working class families. These children were selected from much larger groups when they were either 21 or 31 months old because the child was either consistently shy, timid, and fearful (inhibited) or sociable, bold, and fearless (uninhibited) when he or she encountered unfamiliar people, rooms, and objects. It was necessary to observe over 400 children in order to find 54 consistently inhibited and 53 consistently uninhibited children. The behaviors regarded as definitional of inhibition were a long latency to interact with or retreat from unfamiliar people or objects; remaining near the mother for a long period of time; and cessation of play and/or vocalization. The uninhibited children displayed the complementary behaviors. We observed these children several times after their initial selection and at the last assessment, when they were 7½ years old, recorded their behavior in two different situations. The first was a laboratory play context involving seven to ten unfamiliar children of the same age and sex. The two critical behaviors were the number of spontaneous comments to the other children and long periods of playing or standing apart from any other child in the room. The inhibited children were relative isolates who rarely spoke; the uninhibited children were gregarious and talkative. The second assessment context was as individual testing session with an unfamiliar female examiner. The two critical variables in this setting were latency to the sixth spontaneous comment to the examiner and the total number of spontaneous comments over the testing session. When we combined standardized indexes of the critical behaviors across the two assessments to create an aggregate index, three-fourths of the children maintained their original temperamental category; that is, those who had been classified originally as inhibited were above the median score on this index at 7½ years, while those classified as uninhibited were below the median (Kagan, Reznick, & Snidman, 1988). Carollee Howes (1987) of the University of California has found a similar degree of behavioral consistency in shy and sociable children over the preschool years and these two styles were independent of the amount of social experience the child had with age mates.

Because it may be possible to produce these two different behavioral categories

through environmental experience alone the contention that these two phenotypes are influenced by inherited physiological factors requires additional evidence. One source comes from studies of twins, which reveal that monozygotic twins are more similar in one or the other of these qualities than are dizygotic twins. Both Nathan Fox of the University of Maryland and Adam Matheny of the University of Louisville have found evidence for the heritability of inhibited behavior in young children. Others have reported heritability of fearfulness in infants (Goldsmith & Campos, 1986) and of specific fears in adolescents and adults (Rose & Ditto, 1983). It is not surprising, therefore, that more mothers of inhibited children reported that the child and his or her siblings had unusual fears (going to camp, violent television programs, sleeping in another child's home). Further, about three-fourths of these mothers, compared with one-fourth of the mothers of uninhibited children, told an interviewer that they had experienced panic, agoraphobia, serious and chronic anxiety disorder, or depression (see Figure 1).

The fact that these two groups differ in peripheral physiological reactions that are theoretically reasonable correlates of the contrasting behaviors furnishes additional support for the influence of genetics. Physiologists studying animals in novel contexts have discovered that sites in the limbic system, especially the amygdala and the hypothalamus, have an important influence on fearful and avoidant behavior as well as the sympathetic nervous system and the hypothalamic-pituitary-adrenal axis (Aggleton &

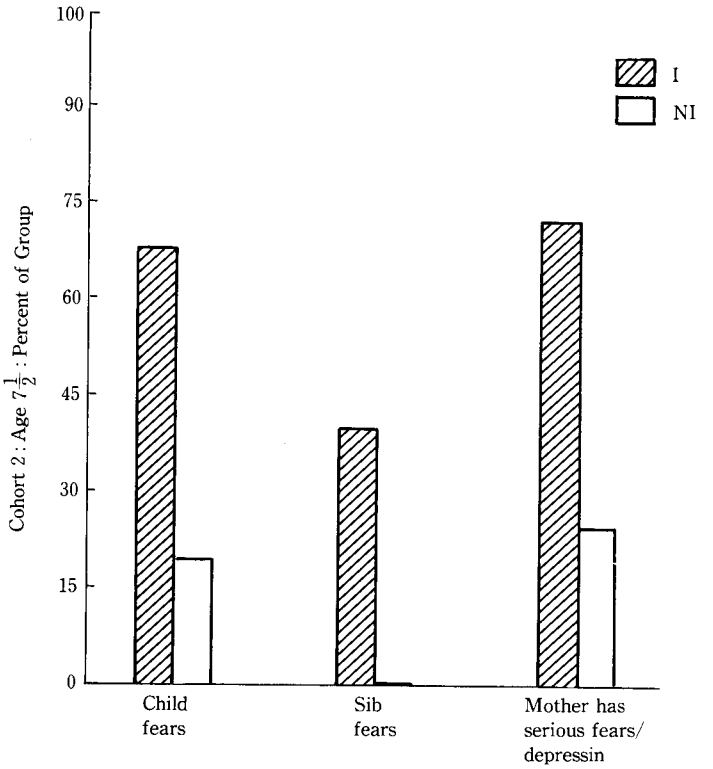
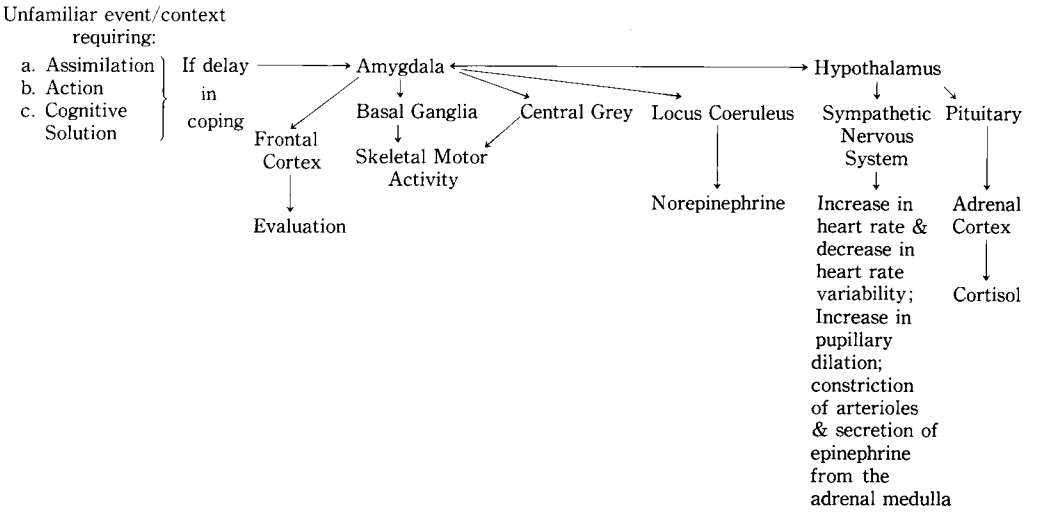


FIGURE 1 Differences between inhibited and uninhibited children selected at 31 months in the frequency of unusual fears, fears among siblings, and anxiety or depression in the mothers.

Mishkin, 1986; Applegate, Kapp, Underwood, & McNall, 1983; Dunn & Everitt, 1988; Rosen & Davis, 1988). But there is intra-specific variation in the reactivity of these circuits. For example, under the stress of restraint members of a fearful rat strain show a profile of neural activity in the central nucleus of the amygdala that is different from the profile displayed by a less fearful strain (Henke, 1988). In a particularly persuasive investigation, Adamec and Stark-Adamec (1986) have discovered that within a sample of house cats (Felis catus) about 15 percent normally retreat from familiar rooms and people and if never exposed to the killing of rats as juveniles will not, as adults, attack rats. A larger proportion of kittens, about 40 percent, behave in just the opposite manner. They rarely retreat from novelty and habitually attack rats. These two behavioral styles are associated with different patterns of brain activity. The defensive cats show greater neural activity in the basomedial amygdala when a rat is introduced into their visual field as well as larger evoked potentials in the ventromedial hypothalamus following stimulation of the basomedial amygdala. These facts imply greater synaptic transmission from the amygdala to the hypothalamus in the fearful cats.

Figure 2 illustrates schematically our hypothesis that the thresholds of excitability of the amygdala and hypothalamus and their projections to the basal ganglia, central grey, sympathetic nervous system, and pituitary-adrenal axis represent an important difference between inhibited and uninhibited children. We now summarize indirect support for this suggestion.



These processes from the basis for a psychological state of uncertainty which is accompanied by a specific physiological state of arousal that some might term anxiety or fear.

FIGURE 2 Schematic diagram of the relation between environmental events and limbic arousal. (If a person cannot deal with unfamiliar or challenging events that require an immediate reaction, sites in the amygdala and hypothalamus are activated and this activation leads, in turn, to changes in motor activity, muscle tone, sympathetic discharge, and secretion of cortisol.)

PHYSIOLOGICAL CHARACTERISTICS OF INHIBITED AND UNINHIBITED CHILDREN

The consistently inhibited children show signs of greater sympathetic arousal to unfamiliarity or challenge as reflected in acceleration of heart rate and increases in pupillary dilation to mild cognitive stress. Further, the children who remained inhibited from 21 months through 7½ years were more likely to have higher and less variable heart rates under cognitive stress than those who remained uninhibited over this same interval (Kagan, Reznick, & Snidman, 1988).

The inhibited children also showed greater skeletal muscle tension than uninhibited children, implying greater activity in the projections from the amygdala to the basal ganglia and central grey. One particularly sensitive index of this tension is a decrease in the variability of pitch periods of single word utterances spoken under stress, which is a consequent of increased muscle tension in the larynx and vocal cords as well as sympathetically mediated constriction of the arterioles serving these muscles (Coster, 1986). It is relevant to note that highly anxious adult women also show greater muscle tension to challenge than do low anxious women (Fridlund, Hatfield, Cottam, & Fowler, 1986).

Inhibited children also maintain higher cortisol levels over long periods of time, which could be due, in part, to greater secretion of corticotropin releasing hormone by the amygdala or the hypothalamus. Although a high cortisol level is a less sensitive characteristic of an inhibited child than are the signs of sympathetic activity described above, children who maintained high levels of salivary cortisol at both 5½ and 7½ years of age in the early morning before the stress of the day had begun were most likely to be inhibited. This fact suggests that the hypothalamic-pituitary-adrenal axis is chronically more reactive in these children. A composite index of limbic arousal at 5 ½ years of age, composed of heart rate, heart rate variability, pupillary dilation, salivary cortisol, urinary norepinephrine, and muscle tension in the larynges and vocal cords clearly differentiated between the children classified as inhibited or uninhibited at 21 mouths of age (Kagan, Reznick, & Shidman, 1988).

Steven Suomi and his colleagues at the University of Wisconsin and the National Institute of Child Health and Human Development have reported similar results with laboratory reared rhesus monkeys (Suomi, in press). This research team has found that about 20 percent of the monkeys show consistently fearful, avoidant behavior when exposed to novelty. The offspring of such monkeys, who are called reactive, display physiological profiles indicative of limbic arousal, for they have higher heart rates and higher cortisol levels than other monkeys, and, as infants, show high levels of motor tension and more fitful sleep patterns. Similarly, Mason and Capitanio (1988) have discovered that individual differences in both heart rate and behavioral signs of fear to novelty were stable over a two year period in rhesus infants reared under two different and very deviant conditions—either with dogs or inanimate objects.

However, the environment has a continuing influence on the developing phenotype for there is always an imperfect predictive correlation between the temperamental qualities of the young infant and later behavior. We believe that the development of a shy, fearful profile at two years of age is enhanced if there is a chronic source of stress during the first two years of life which actualizes the high level of limbic arousal into

the behavioral phenotype we call inhibited. A variety of stressors are potentially potent; for example, marital strife, divorce, parental death, serious illness in a family member, or frequent moves. However, these stressors were not frequent in most of the families in our longitudinal cohorts. An unanticipated finding suggested a potential source of chronic stress we had overlooked. In both of our longitudinal cohorts more inhibited children were later born while more uninhibited children were first born. Further, the children who had been classified as inhibited originally, but had changed their profile to resemble that of the average child, were more often first borns, while inhibited children who retained their fearful style were more often later borns. On reflection, this association is reasonable. A three or four year old child is likely to poke, prod, and frustrate his or her younger infant sibling on an unpredictable schedule. This experience may not constitute a risk factor for the average infant. But, for the 15 percent who are both with a low threshold of limbic reactivity to stress, such daily experiences could actualize the temperamental predisposition into the profile we call the inhibited child.

It is important to add that we regard the categories inhibited and uninhibited as representing qualitatively different temperamental types and do not conceive of these children as lying on a continuum from shy to sociable. Support for this belief is the fact that shy and sociable behavior are only preserved from the first to the fourth birthday in children who fall at the extremes of a distribution of scores measuring their social behavior (Kagan, Reznick, & Gibbons, 1989). There is minimal preservation of shy or sociable behavior for the 60 percent of children whose scores are not at the extreme and the association between inhibited behavior and signs of sympathetic reactivity only holds for the extremely shy children.

INFANT PREDICTORS

In order to discover the qualities of young infants that might predict the emergence of an inhibited or an uninhibited style in the second year, we are studying 120 healthy Caucasian infants born at term from a volunteer sample of families. No other criterion, behavioral or physiological, was imposed on the selection of the children. All of these infants have been observed in our laboratory at 2 and 4 months of age and are now being assessed at 9, 14, and 21 months of age. The mothers remain with their infants during the laboratory assessments.

The two month old infants were filmed and their heart rates recorded while they encountered a series of unfamiliar visual, olfactory, and auditory stimuli. For example, the two month old infants saw a series of small objects move slowly back and forth in front of their eyes, heard a taped female voice speaking short sentences, and were presented with a cotton swab that had been dipped in a low concentration of butanol. The four month old infants saw mobiles containing varying numbers of objects and heard a taped female voice speaking three different nonsense syllables at three levels of loudness.

The degree of motor arousal produced by these stimulus events is one of the most obvious behavioral differences among the infants. About two-thirds of the children display very similar behavior. They orient to the stimulus and show a small

amount of motor activity, most often an occasional protrusion of the tongue and a flexor movement of an arm or leg. However, the behavior of a small group—about 15 percent—is qualitatively different. These infants display extreme levels of motor arousal. Their tongue often protrudes completely from their mouth, legs pump repeatedly, the back is arched, and, on occasion, the arms extend in front of the body with such tension the limbs are momentarily spastic. This extraordinary degree of motor arousal is qualitatively different from the magnitudes displayed by the majority of infants. It is important to add that spontaneous vocalization, or babbling, is not highly correlated with motor activity.

Frequent fretting or crying to the stimuli is a second behavior that differentiates the infants. Although crying is much less frequent at four than at two months, motor arousal is considerably higher at the older age. Although most infants fretted only a few seconds, and some did not fret at all, about 15 percent fretted or cried frequently, usually with intensity and, in addition, were difficult to soothe. The fretting often occurred during or immediately following a period of high motor arousal, creating the impression that a distressed state was provoked as the level of motor arousal passed a threshold value.

We observed these children again when they were 9 and 14 months old in a series of situations designed to evaluate their predisposition to display fear to the unfamiliar. The incentives were unfamiliar events in a small testing room with a female examiner as well as encounter with unfamiliar adults and objects in a large playroom. For example, at both 9 and 14 months the female examiner uncovered a small, unfamiliar toy that rotated slowly on a base. After first permitting the child to watch the toy rotate for a few seconds, she uttered a nonsense phrase in a pleasant voice with a smile on her face on two successive trials. On the subsequent two trials the examiner suddenly changed her mood by frowning and speaking the same nonsense phrase with a stern voice. Some children displayed a facial expression indicative of apprehension and cried on one or both of these unexpected discrepant trials. About fifteen minutes later, after a period of free play with toys in a large playroom, an unfamiliar woman entered the room and sat on the floor. After remaining quiet for one minute the woman began to play quietly with a toy she had brought with her, and one minute later began to talk. If the child had not yet approached her, the stranger invited the child to approach and to play with her and the toy. She then walked over to a small cabinet in a corner of the room, opened it, and revealed a metal robot about 3 feet tall. Most of the 9 and 14 month old children approached the stranger and the robot within two minutes. However, a smaller number approached neither the stranger nor the robot and some retreated to the mother.

There were ten occassions on which each of 76 infants could show obvious signs of fear; namely, a wary face accompanied by fretting, crying, or obvious retreat from a discrepant object. Figure 3 shows the differential occurrence of fearful behavior at 9 and 14 months as a function of the infant's behavior at four months. More of the 24 highly fearful children (fear on four or more occasions) showed high motor arousal, high crying, and a high heart rate compared with the 22 minimally fearful children (fear on none or one occasion) who behaved in the opposite way. Six (25 percent) of

the children who showed high fear at both 9 and 14 months were above the mean on motor arousal, crying, and heart rate at four months of age and not one of the 24 children was below the mean on these three qualities. By contrast, fourteen (63 percent) of the children who showed minimal fear at 9 and 14 months were below the mean on the three arousal characteristics and not one showed a high level of motor arousal, fretting, and heart rate. It is reassuring that Fox (1989) has also found that 14 month old infants who were inhibited in an unfamiliar laboratory setting had higher and more stable heart rates at five months of age than did the minimally fearful children. As can be seen in Figure 3 low motor arousal at four months was the best predictor of minimally fearful behavior at nine and fourteen months. At two months of age the children who would become fearful smiled less often to the stimuli, were more distressed by a low concentration of butanol and were less likely to complete the battery because of excessive irritability (See Figure 4).

These results can be understood in a preliminary way as a result of physiological research during the last decade. The lateral and basolateral nucleus of the amygdala receive inputs from the secondary association areas of the auditory and visual modalities. These nuclei project, in turn, to the nucleus accumbens, ventral striatum and ventral pallidum and, thence, to the skeletal motor system. The high levels of motor arousal displayed to the mobiles and human speech at four months could be a consequent of low thresholds of reactivity in this circuit. As a result, the infant protrudes his or her tongue and extends legs and arms in an excited, vigorous manner.

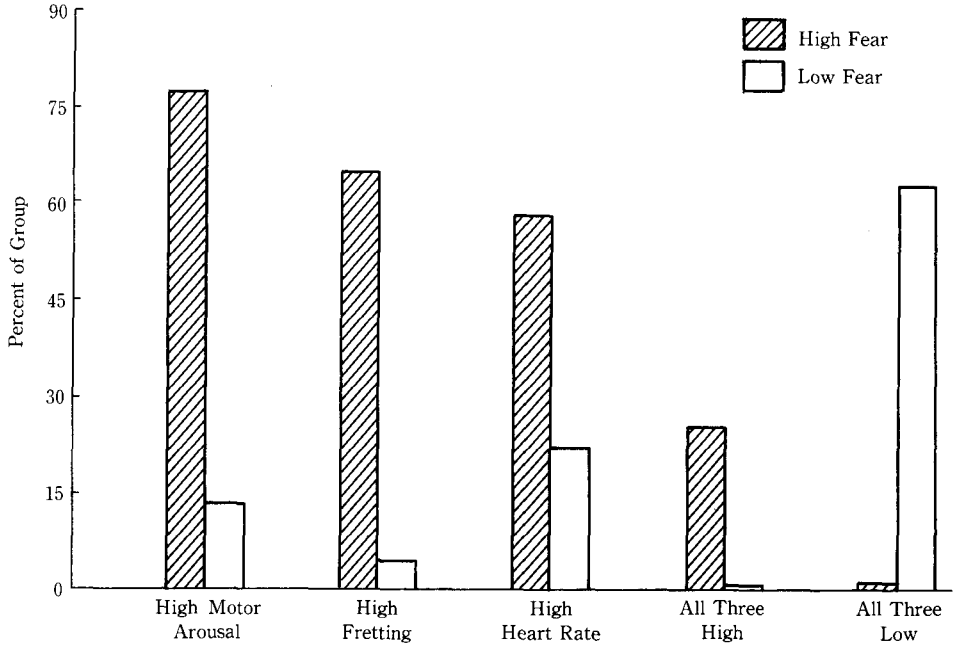


FIGURE 3 Percent of fearful versus fearless children who displayed high motor arousal, fretting, and heart rate at 4 months of age.

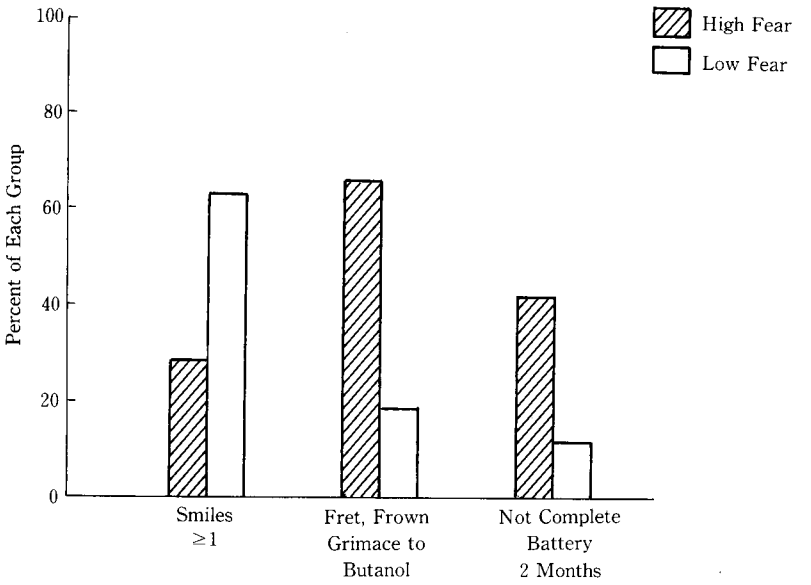


FIGURE 4 Percent of fearful versus fearless children who displayed at least one smile, dysphoric affective reaction to butanol, and failure to complete the battery at 2 months of age.

The central nucleus of the amygdala is a major origin of autonomic reactivity, and perhaps, crying. Further, because the basolateral nucleus synapses on the central nucleus, high levels of activity in the former can lead to enhanced excitability in the latter. As a result, behavioral distress and a rise in heart rate to stress should occur. Thus, it is reasonable that infants born with a low threshold of reactivity in the amygdala would show high motor arousal, high irritability, and a high heart rate to unfamiliar events—the profile characteristic of the fearful 14 month old children. Infants born with a high threshold of reactivity should display low motor arousal, low fretting, and a low heart rate.

If inhibited and uninhibited children differ inherently in the excitability of the amygdala and its projections to the hypothalamus and basal ganglia, a next important question asks about the origins of this variation in limbic arousal. Although anatomical differences in limbic structure are always possible, the history of research in this domain of inquiry suggests that the differences in limbic states are more likely to be the result of inherited variation in the profiles of neurotransmitters, hormones, and brain peptides and/or the number of receptors for these substances (McGeer, Eccles, & McGeer, 1987). As Edward Kravitz (1988) notes, the different chemical profiles in the central nervous system " act as gain-setting devices, biasing the behavior of animals towards specific stereotypical responses...to particular types of stimulation ", (page 1780). Two possible candidates are corticotropin releasing hormone and norepinephrine. The presence of either lowers the threshold of reactivity in the amygdala and each is an agonist of the other.

SUMMARY

Although the evidence presented indicates that extreme degrees of timidity and shyness, on the one hand, or boldness and sociability, on the other, are associated with physiological processes that could be genetically mediated, two caveats are appropriate. First, the child's biology does not guarantee the development of an inhibited or an uninhibited profile in later childhood. At least half of the children selected as inhibited at twenty-one or thirty-one months were not extremely shy or timid at 7½ years of age and 10 percent of the uninhibited children had become shy. We presume these changes were the result of intervening experiences and noted the importance of one such experience; namely, the presence of an older sibling. The child's biology is not deterministic.

Second, inhibited behavior is not necessarily maladaptive, especially in industrialized societies. Inhibited children prefer to play alone rather than with a large group of peers. If they are living with families who promote academic achievement some of them will attain excellent academic records which will motivate them to select rewarding careers that require solitary intellectual activity, including science, computer programming, history, music, and art.

It is likely that a large number of equally significant temperamental categories will be discovered in the future. As technology and theory advance, it is probable that more disguised temperamental categories will be detected. These new categories may help us understand clinical phenomena like attention deficit disorder and anorexia and might provide some insight into unusual mathematical, verbal, and artistic talents.

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